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Quarterly Technical Progress Report

No. 6329-27

on the

DEVELOPMENT OF METALLIZATION PROCESS

FSA Project, Cell and Module Formation Research Area

For the Period Ending

June 30, 1984

Contract 956205

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Approved by:

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Sylmar, California 91342

July 1984

The JPL Flat Plate Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE.

ABSTRACT/SUMMARY

New pastes were evaluated that contained additives to aid in the silicon-to-metallization contact. None were completely successful. A reevaluation of the molybdenum oxide paste and the two-step screen printing process was done. The oxide paste did not show promise. The two-step process enabled soldering of the cells but the cells still had a high series resistance. Pastes are on order from a different manufacturer.

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Section 1.0

INTRODUCTION

The objective of this contract is the optimization, evaluation, and demonstration of a novel metallization applied by a screen printing process. The process will be evaluated on both CZ and non-CZ silicon wafers.

Section 2.0

TECHNICAL DISCUSSION

Based upon the SEM work done on the heated stage at Mircoscopy Research Laboratories, Inc. a set of experiments was done using the L paste and sintering for long periods of time at lower temperatures without drying. It was hoped that the nonwetting of the molten tin particles was caused by an oxide which would be broken down in time by reaction with hydrogen. Cells were printed, dryed and placed in the sintering furnace under H_2 at 400°C. After 4 hours in the furnace cells did not show signs of sintering. Two new pastes were procured from Electrink. Table 1 shows the formulations. These formulations were based on experience at Electrink on silver inks. Paste S is similar to Paste J with silver flake added and Paste T has bismith added. The printed cells were sintered at temperatures of up to 650°C but did not show good curve shape. Typical light and dark curves are shown in Figures 1 and 2. Higher temperatures and longer times produced low shunt resistances. Both S and T behaved in a similar fashion.

More experimentation was done on the molybdenum oxide paste (Paste M). Sintering temperatures up to 825°C under H_2 were used. The best cell IV curves are shown in Figures 3 and 4. Cells fired at higher temperatures showed severe shunts. The low short circuit current is difficult to explain and may be due to an opaquing layer forming on the cell surface. Cells fired at temperatures of 825 and 850°C showed metallic-like

Table 1

PRODUCT INFORMATION

Formulation % by Weight

Item	F-86	F-87
Titanium Hydride (TiH_2)	.55	.55
Molybdenum Powder	14.40	14.40
Tin Powder	57.60	57.60
Frit L1571A	4.45	4.45
Silver Flake Type C	8.00	-
Bismuth Powder	-	8.00
Vehicle V-38	15.00	15.00
Identification	S	T

Vehicle Formulation

Item	V-38
α-terpineol	43.62
Butyl Carbitol Acetate	43.62
Ethyl Cellulose N-14	9.76
Thixatrol ST	3.00

Table 1 (continued)

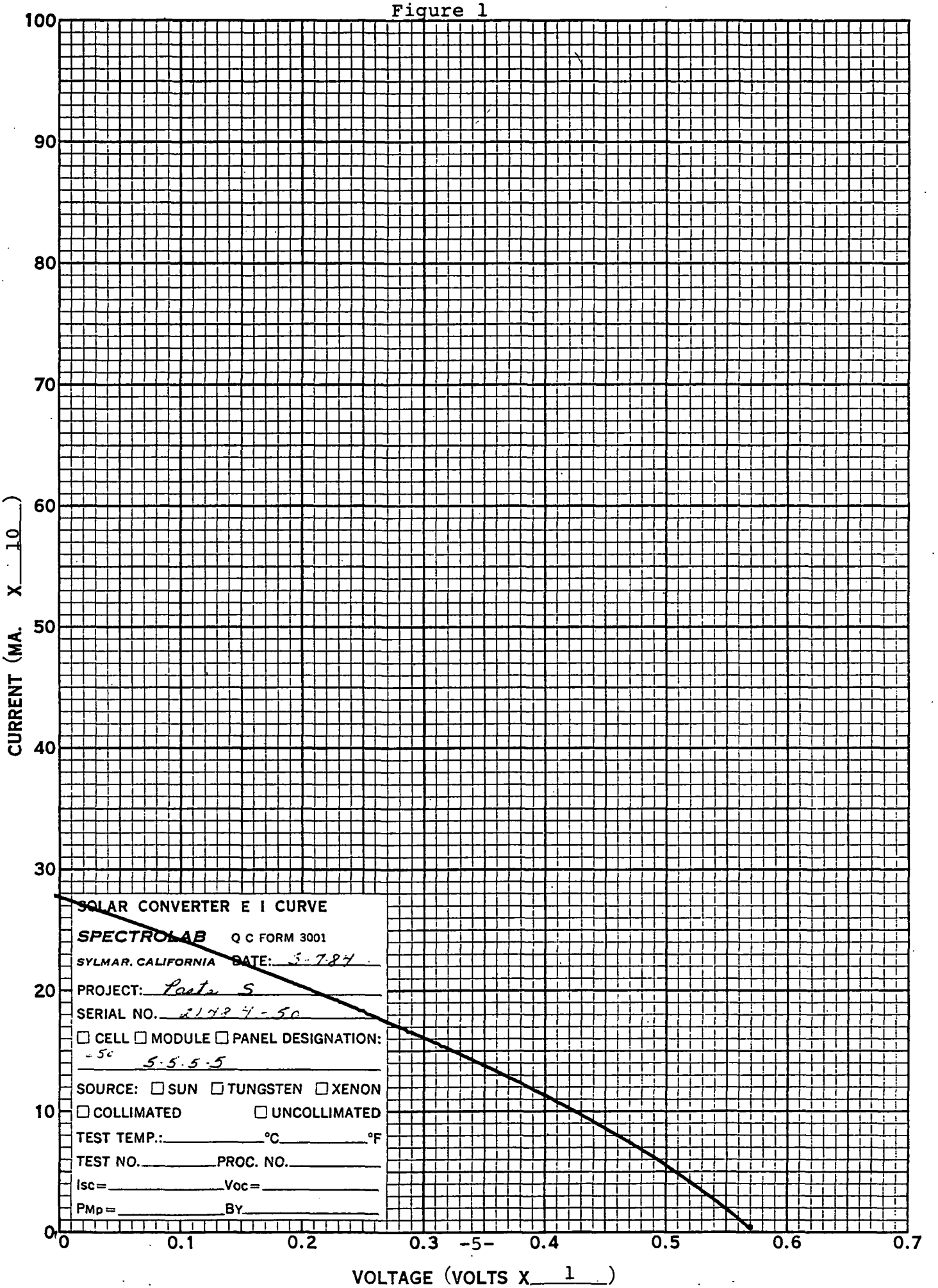
Frit Composition - % by Weight

Item	Frit L1571A
PbO	60
B_2O_3	30
SiO_2	10

Materials Sources

Material	Designation	Source
Titanium Hydride (TiH_2)	77113	Alfa-Ventron, Danvers, MA
Silver Flake	C	Metz Meta-lurgical, Plainfield, Nj
Molybenum Powder	280/325	GTE Sylvania, Towanda, PA
Tin Power 325 Mesh	00352	Alfa-Ventron, Danvers, MA
Frit No. L1571A	L1571A	Americal Porcelain Enamel Co. Muskegan, Mich.
α-terpineol	TX 75	MCB Chem. Cincinnati, OH
Butyl Carbitol Acetate	BX 1722	MCB Chem. Cincinnati, OH
Ethyl Cellulose	N-14	Hercules, Wilmington, DE
Thixatrol (thickner)	ST	NL Industries, Hightstown, NJ
Elvacite (acrylic resin)	2042	Dupont, Wilmington, DE
Bismuth Powder	00046	Alfa-Ventron, Danvers, MA

Figure 1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CURRENT (MA. X 10)
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VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 5-7-84
PROJECT: Poets 5
SERIAL NO. 2142-4-50
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
-5c 5.5.5.5
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
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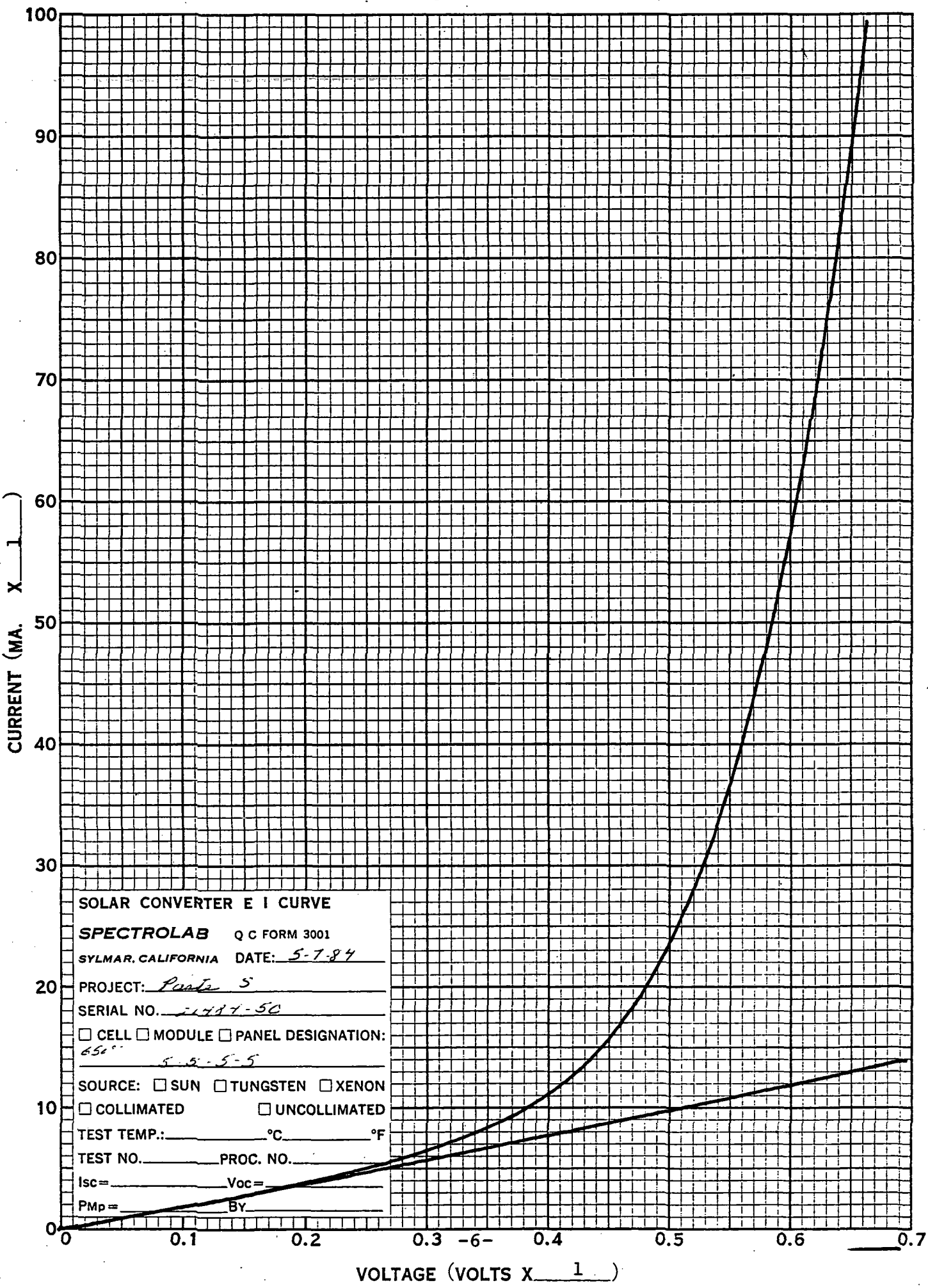
TEST NO._____PROC. NO._____
Isc=_____Voc=_____
PMp=_____BY_____

Figure 2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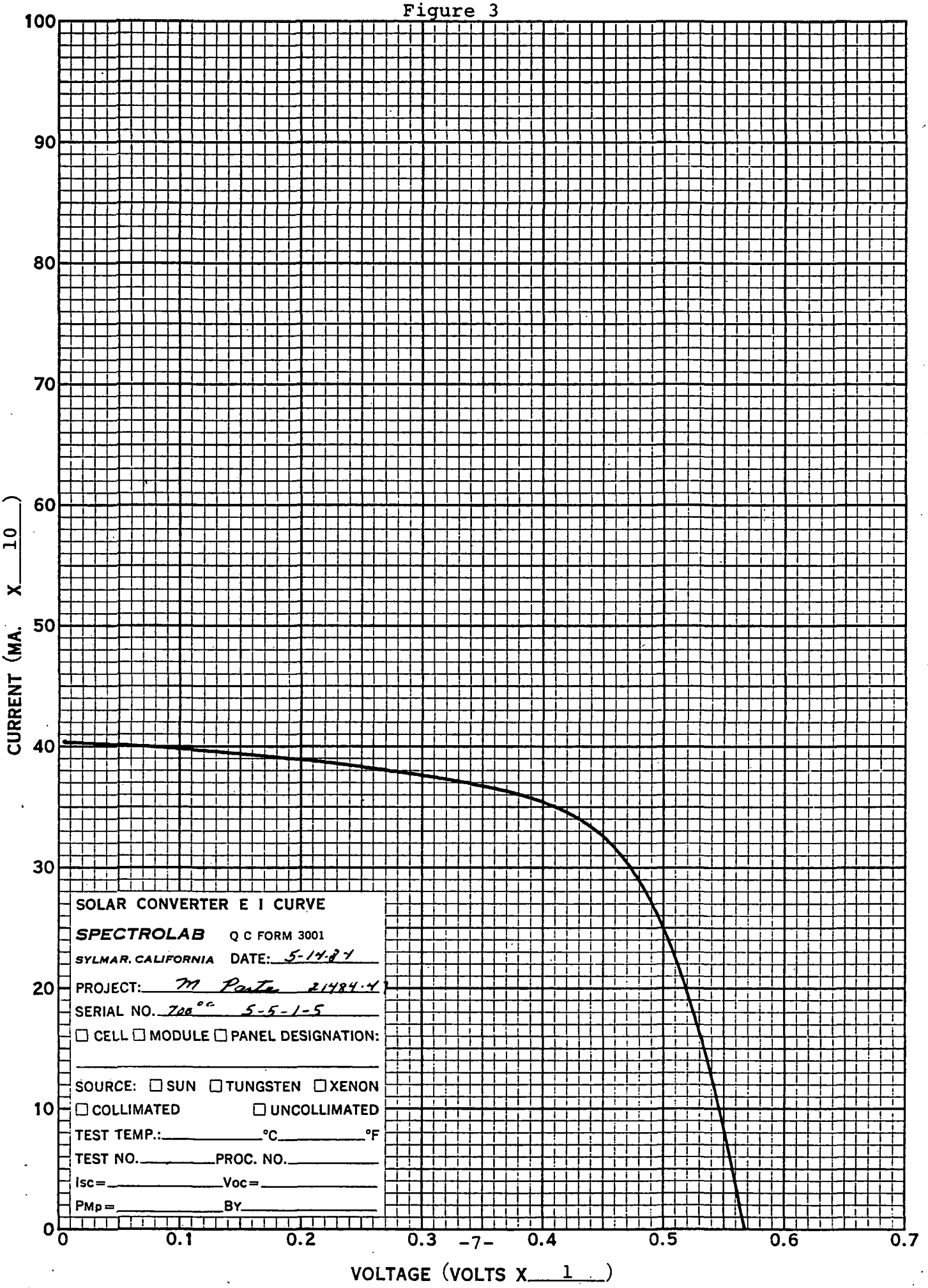
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 5-7-84
PROJECT: Panle 5
SERIAL NO. 1777-50
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
65c° 5-5-5-5
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.:_____°C_____°F
TEST NO._____PROC. NO._____
Isc=_____Voc=_____
PMp=_____BY_____

Figure 3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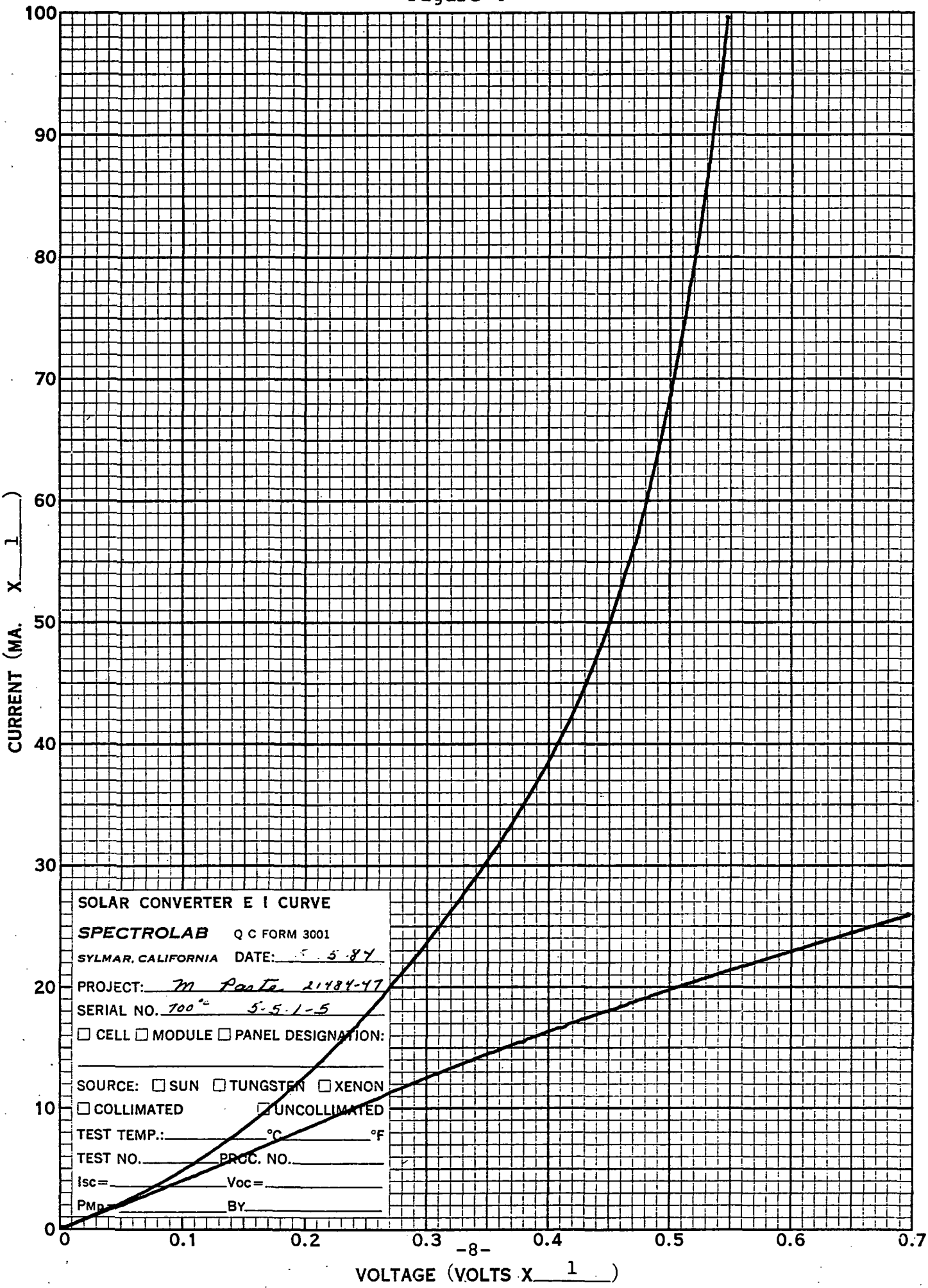
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 5-14-84
PROJECT: M Parts 21484-4
SERIAL NO. 200°C 5-5-1-5
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: °C °F
TEST NO. PROC. NO.
Isc= Voc=
PMp= BY

Figure 4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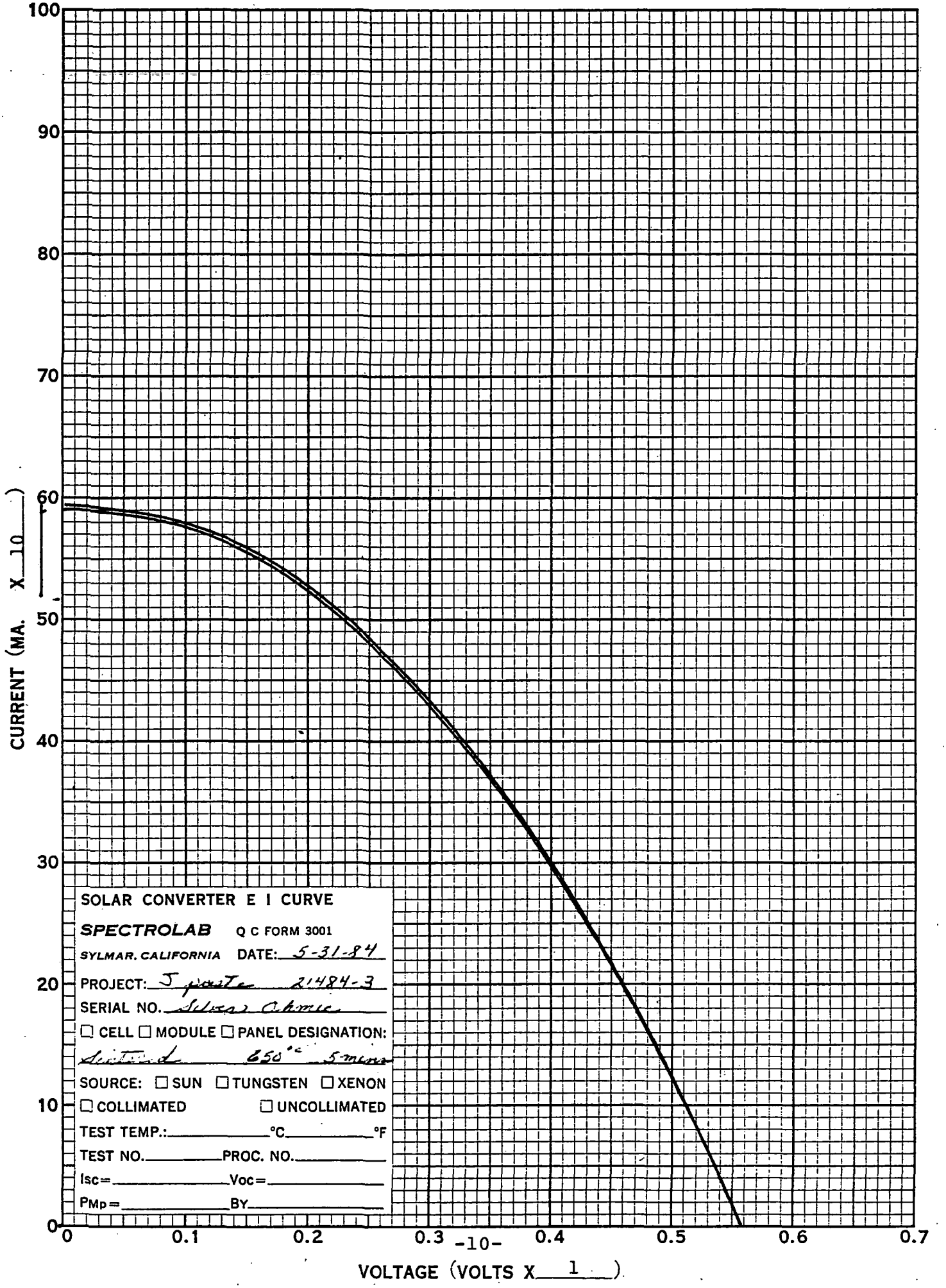
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 5 5 84
PROJECT: M Pasta 21484-47
SERIAL NO. 700°c 5-5-1-5
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: °C °F
TEST NO. PROC. NO.
Isc= Voc=
PMp= BY

grid patterns which were solderable. However, none of the solderable cells had measurable IV curves. Spectrolab has been unable to reproduce earlier research done on this paste system.

The use of a two-step screen printing sequence was reexamined. Cells were first printed with J and E pastes, and prefired at 600°C. The pattern left the soldering pad bare. Silver paste was then printed over the solder pad area overlapping onto the Mo/Sn metallization. The cell was then fired in air at 750°C (48"/min., 24" zone at 400°C and 18" zone at 750°C). The cells were sintered in H_2 for 5-30 min. at 600-650°C. The best cell is shown in Figures 5 and 6. There is good continuity between the ohmic pad and the rest of the metallization but series resistance is too high.

The problems of this experiment may be due to the paste used. Earlier work was done using Thick Film Systems' Paste F-503. The two pastes used here are Electrink equivalents. To ensure reproducibility an order has been placed for the Thick Film Systems' F-503 paste. Paste F-503 will be used exclusively in further work on the two-step process.

Figure 5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CURRENT (MA. X 10)
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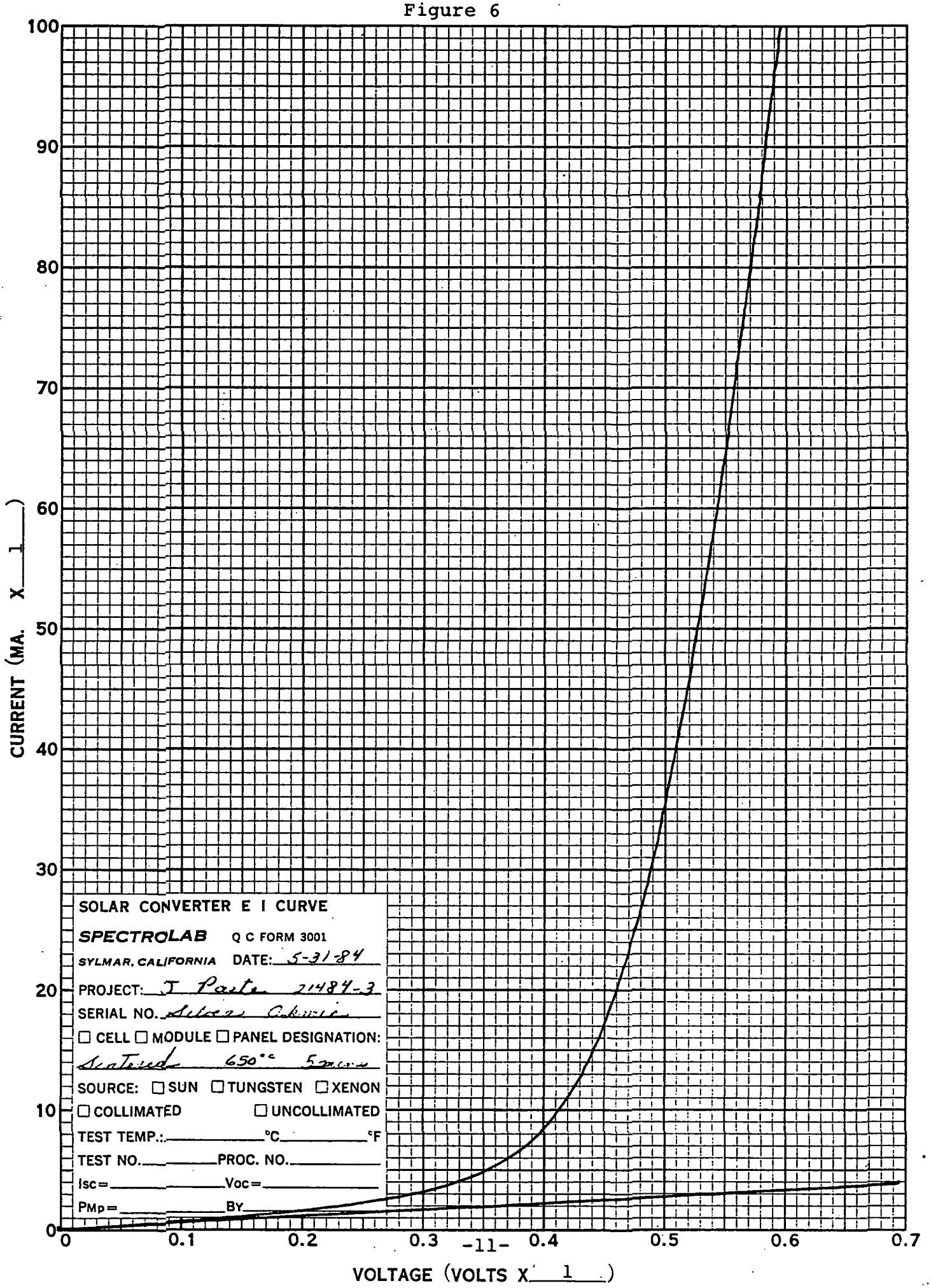
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 5-31-84
PROJECT: Spartan 21484-3
SERIAL NO. Silicon Chemie
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
Sintered 650°C 5-mins
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.:_____°C_____°F
TEST NO._____PROC. NO._____
Isc=_____Voc=_____
PMp=_____BY_____

Figure 6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CURRENT (MA. X 1)
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0.2
0.3
0.4
0.5
0.6
0.7
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 5-31-84
PROJECT: J Poole 21484-3
SERIAL NO. Silicon Cohmic
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
Sintered 650°C 5 min
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.:_____°C_____°F
TEST NO._____PROC. NO._____
Isc=_____Voc=_____
PMp=_____BY_____

Section 3.0

CONCLUSION AND RECOMMENDATIONS

There are no conclusions or recommendations to report for the period.

Section 4.0

ACTIVITIES PROJECTION

During the next quarter additional pastes will be evaluated. Work on the two-step process will continue with the new paste. Economic analyses of the processes will be done using an IPEG analysis. The program will be concluded in this quarter.